Dealing with structural correlation in discrete choice models: The complex case of route choice

Evanthia Kazagli

Transport and Mobility Laboratory
School of Architecture, Civil and Environmental Engineering
École Polytechnique Fédérale de Lausanne

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Agenda

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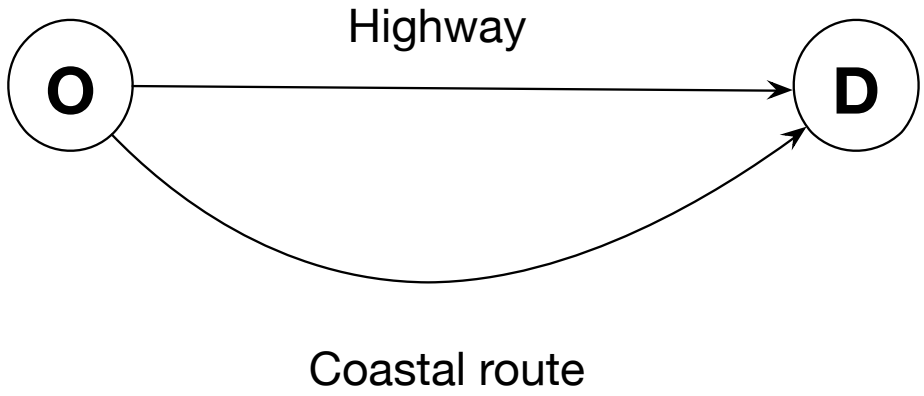
Route choice

Predict the route that a traveler would choose to go from the origin (O) of her trip to the destination (D) of her trip.



- One of the key travel demand models.
- Distribution of travelers on the network.

  ✓ Planning and real time operations and guidance

- Need to go beyond the shortest/ fastest path models.

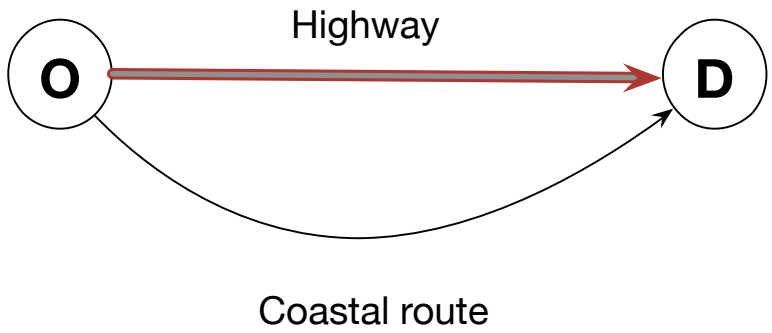
Route choice modeling

Goal

Understand, describe, predict route choice behavior.

→ Discrete choice analysis:

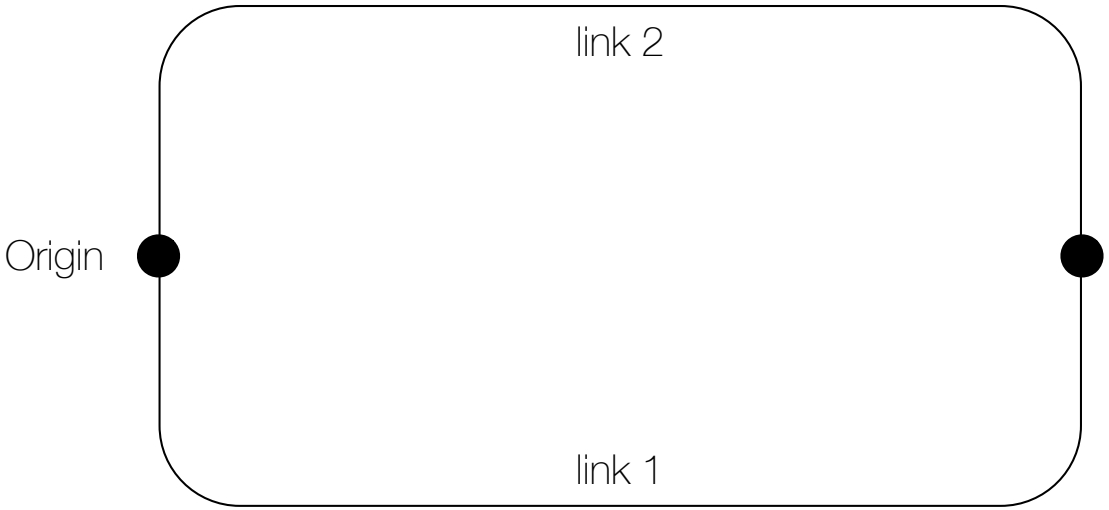
Behavior is an outcome of choice.



Motivation

Simple example

only length influences the choice



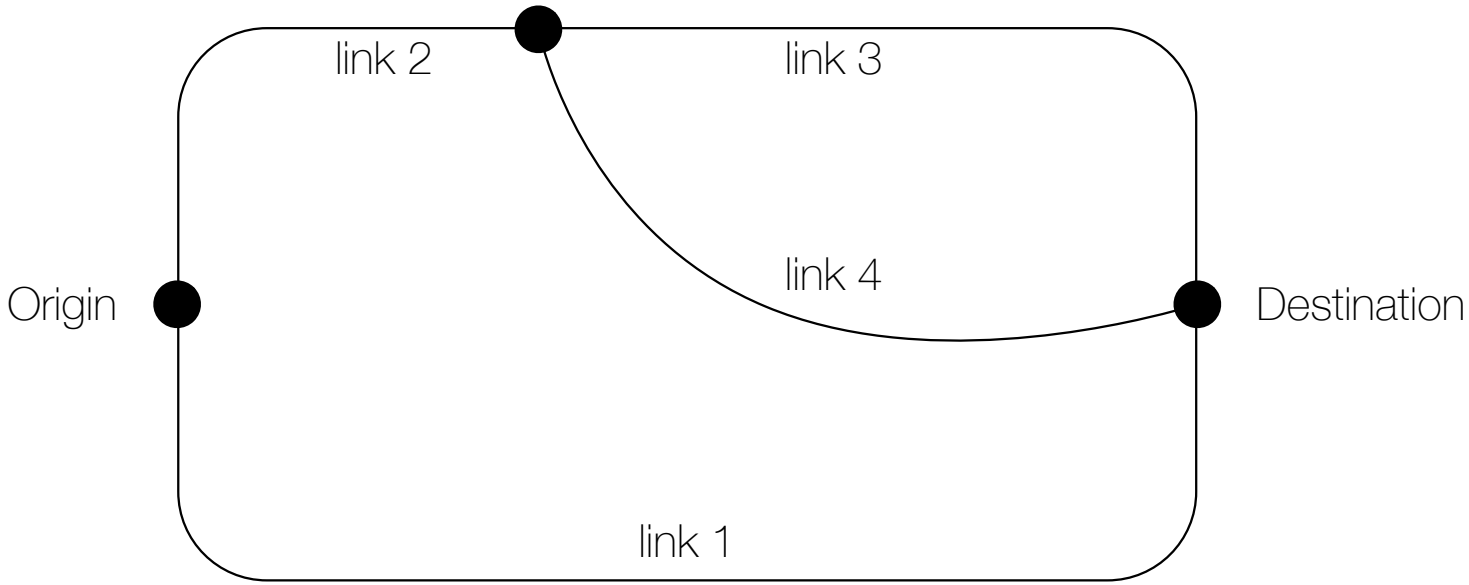
L_link1 = 10
L_link2 = 10

logit probabilities

P(link1|{link1, link2}) = 1/ 2
P(link2|{link1, link2}) = 1/ 2

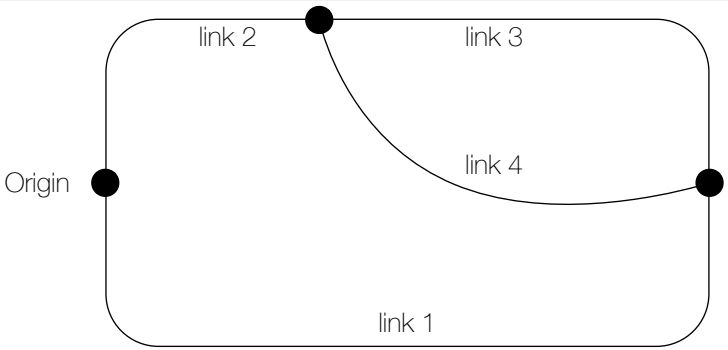
Simple example

now let's assume that a new link is added



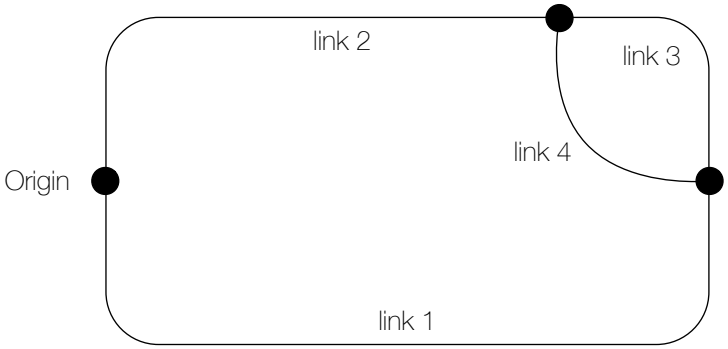
Simple example

what happens to the logit choice probabilities?



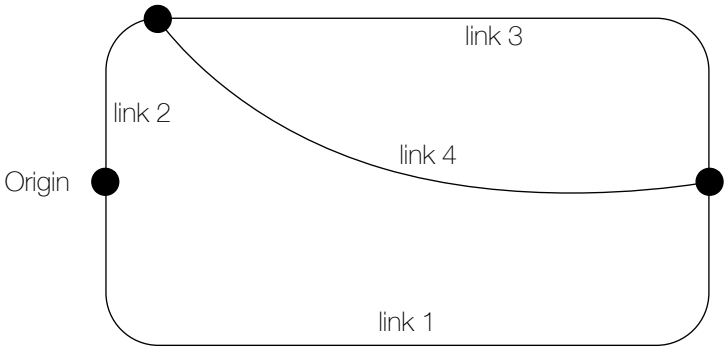
L_link1 = 10
L_link2 = 5
L_link3 = L_link 4 = 5

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33



L_link1 = 10
L_link2 = 9
L_link3 = L_link 4 = 1

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33



L_link1 = 10
L_link2 = 1
L_link3 = L_link 4 = 9

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33

Adopted from Vovsha and Bekhor (1998)

Different approaches to deal with correlation

1. In the determinist part of the utility.
   - ⊙ Simple but not realistic.
   - ⊙ C-logit (Cascetta et al., 1996); Path size logit (Ben-Akiva and Bierlaire, 1999)
2. In the stochastic part of the utility.
   - Realistic but complex.
   - Link nested logit/ cross nested (Vovsha and Bekhor, 1998; Lai and Bierlaire, 2015); Logit kernel (Bekhor et al., 2002; Frejinger and Bierlaire, 2007)

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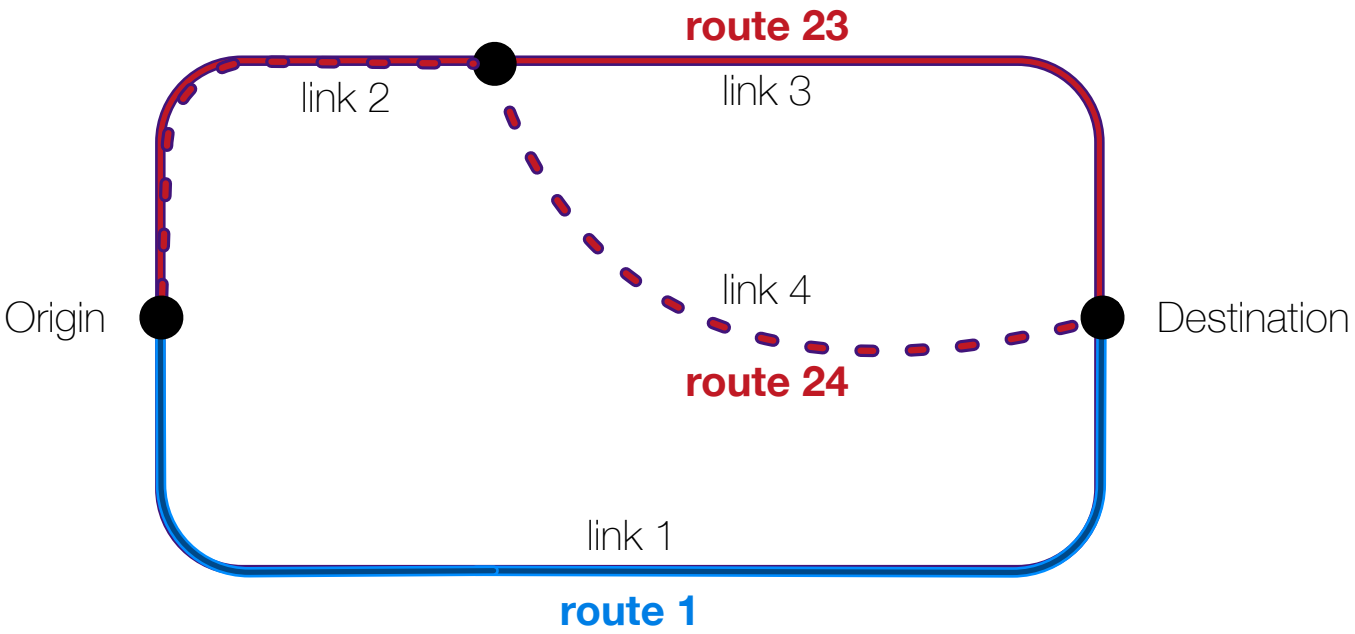
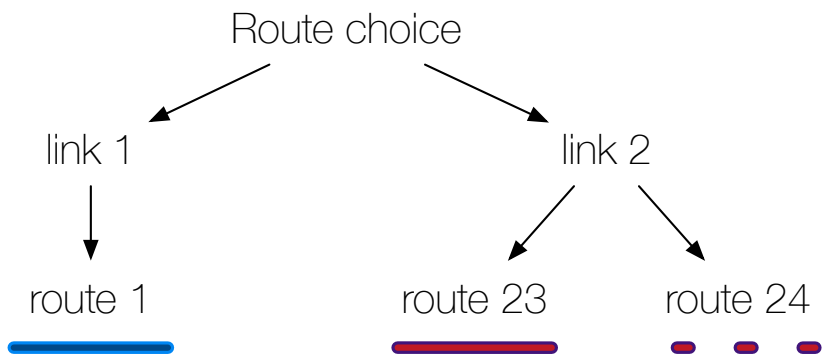
Capturing the correlation

The nested logit model



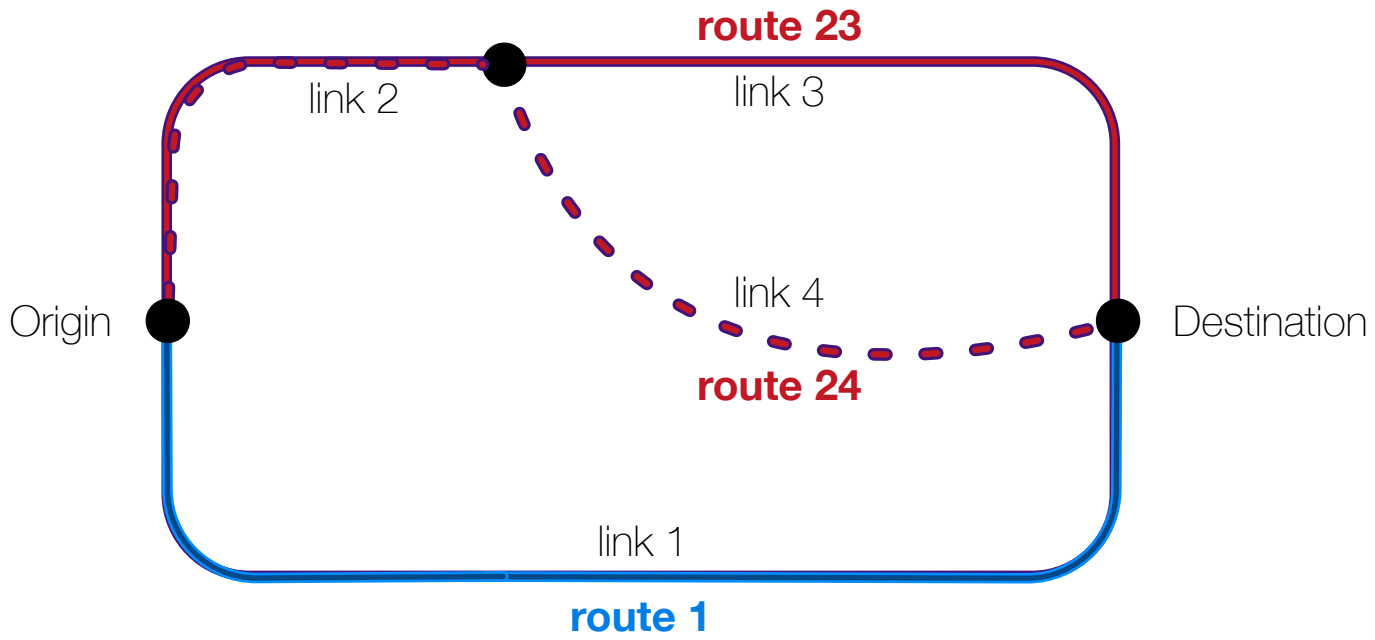


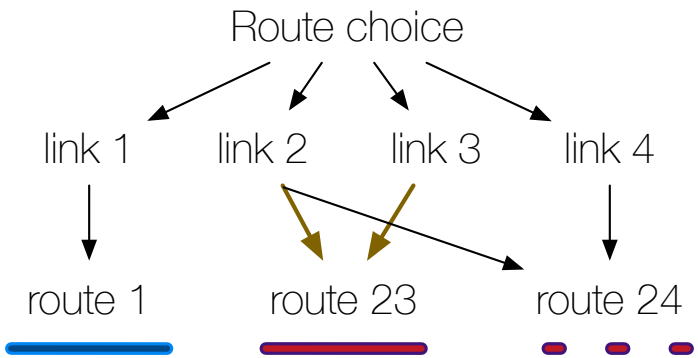
logit

expected maximum utility of route 23 and 24

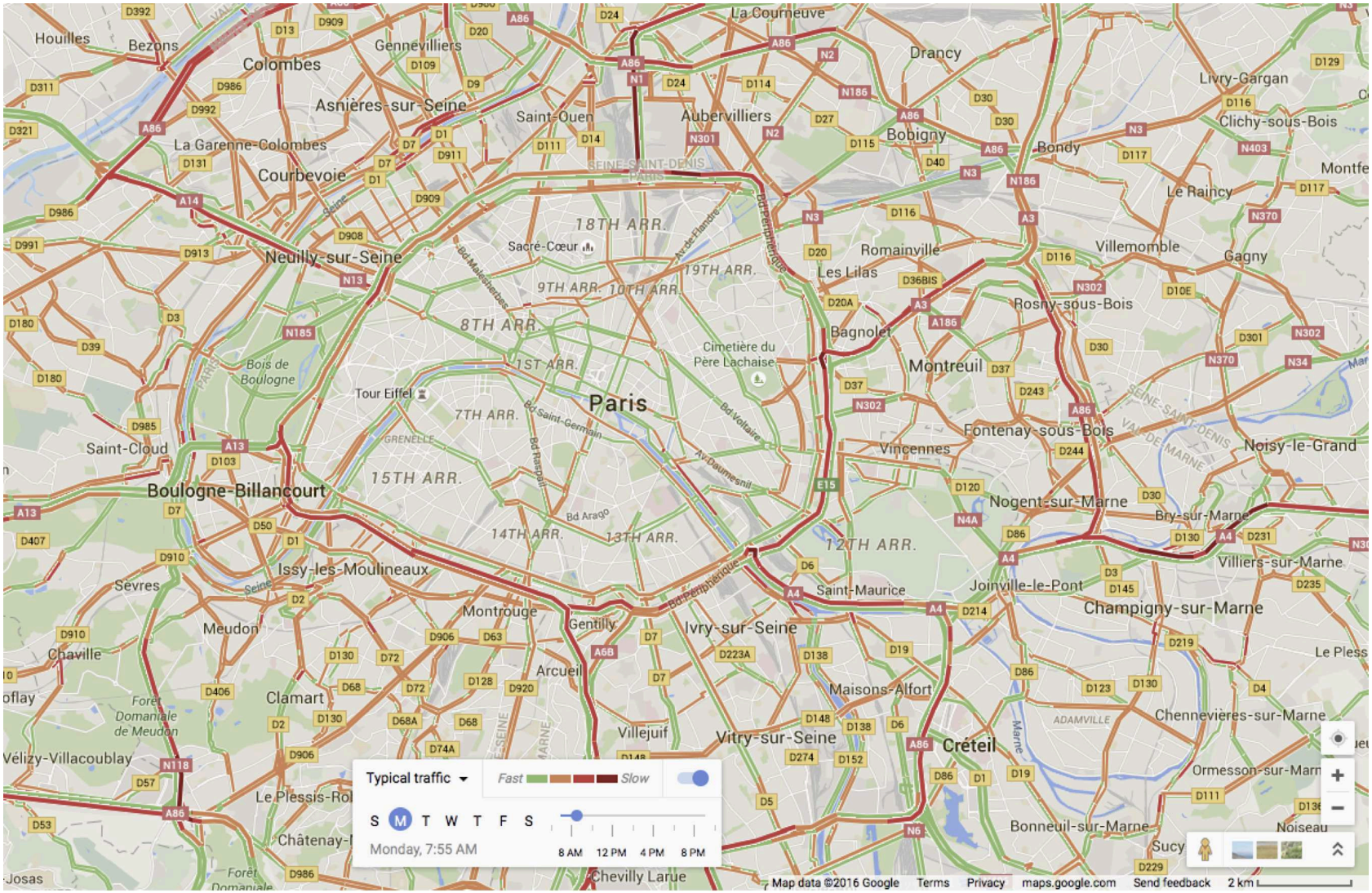
Capturing the correlation

The cross nested logit model





But what happens when...



Capturing the correlation

from logit to CNL *the # of parameters to be estimated explodes*

$$P(i|\mathcal{C}_n) = \frac{e^{\mu V_{in}}}{\sum_{j\in\mathcal{C}_n} e^{\mu V_{jn}}}$$

$$P(i|\mathcal{C}) = \frac{e^{\mu_m V_i}}{\sum_{j\in\mathcal{C}_m} e^{\mu_m V_j}} \frac{\left(\sum_{\ell\in\mathcal{C}_m} e^{\mu_m V_\ell}\right)^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M}\left(\sum_{\ell\in\mathcal{C}_p} e^{\mu_p V_\ell}\right)^{\frac{\mu}{\mu_p}}}$$

$$P_n(i) = \sum_{m=1}^{M} \frac{\left(\sum_{j\in\mathcal{C}_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}}\right)^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M}\left(\sum_{j\in\mathcal{C}_n} \alpha_{jp}^{\mu_p/\mu} e^{\mu_p V_{jn}}\right)^{\frac{\mu}{\mu_p}}} \frac{\alpha_{im}^{\mu_m/\mu} e^{\mu_m V_{in}}}{\sum_{j\in\mathcal{C}_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}}}$$

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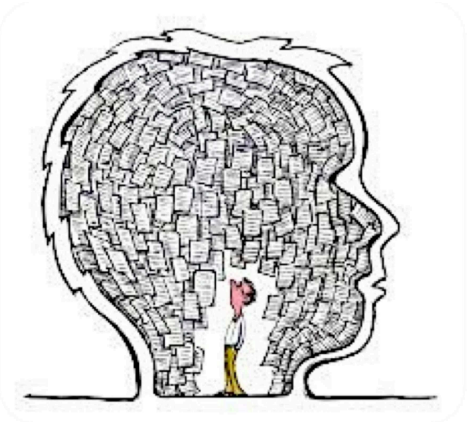
The MRI approach

How can we represent a route in a behaviorally realistic way without increasing the model complexity?

→ Model the strategic decisions of people instead of the *operational* ones.

✓ Mental Representation Item (MRI)

Kazagli, E., Bierlaire, M., and Flötteröd, G. (2015). Revisiting the Route Choice Problem: A Modeling Framework Based on Mental Representations. Technical report TRANSP-OR 150824. Transport and Mobility Laboratory, ENAC, EPFL.

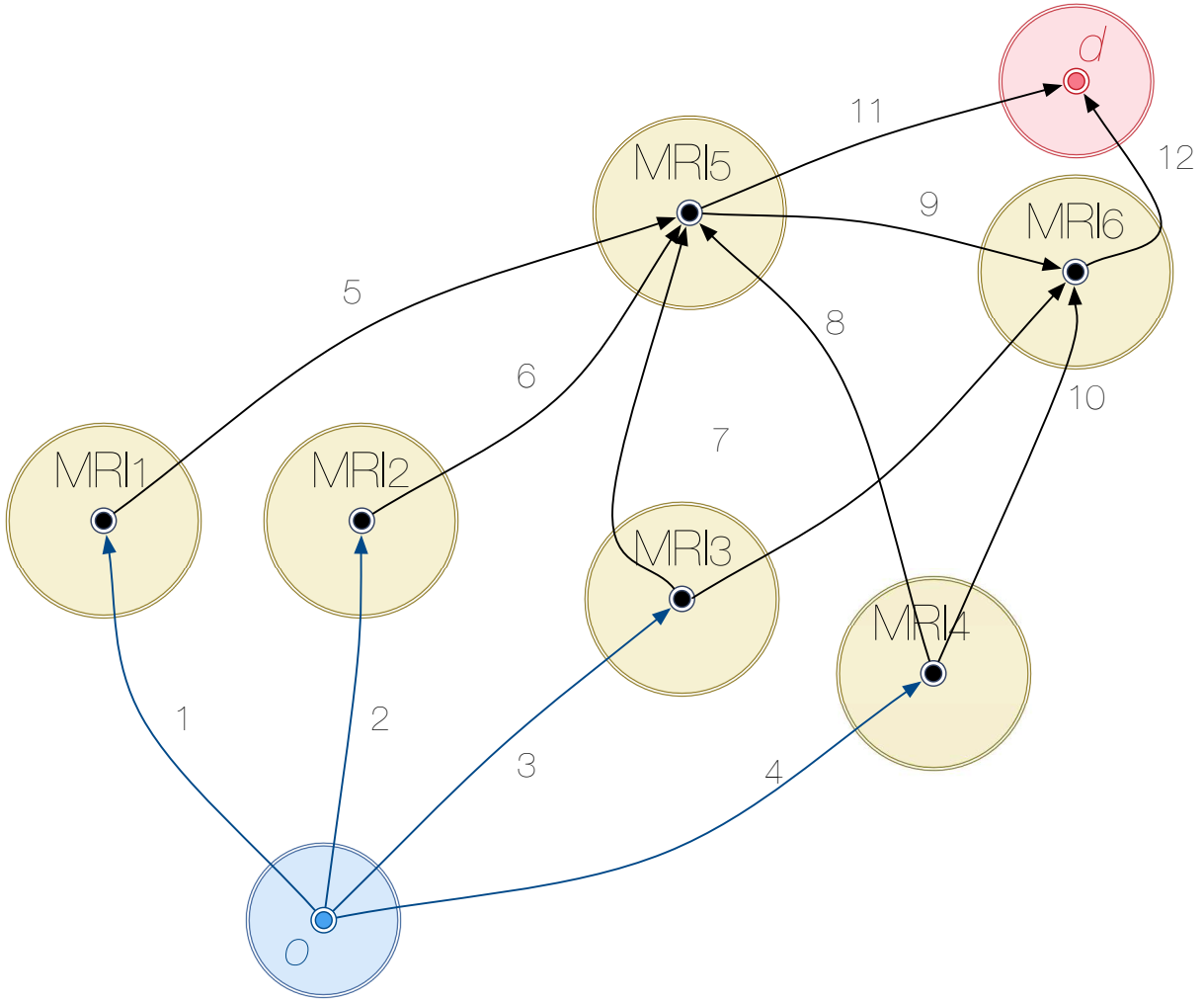


The MRI definition

Examples of two MRIs and their components

The MRI choice set

For a real city in Sweden we were able to abstract the network and describe the route choice set using 6 MRIs.

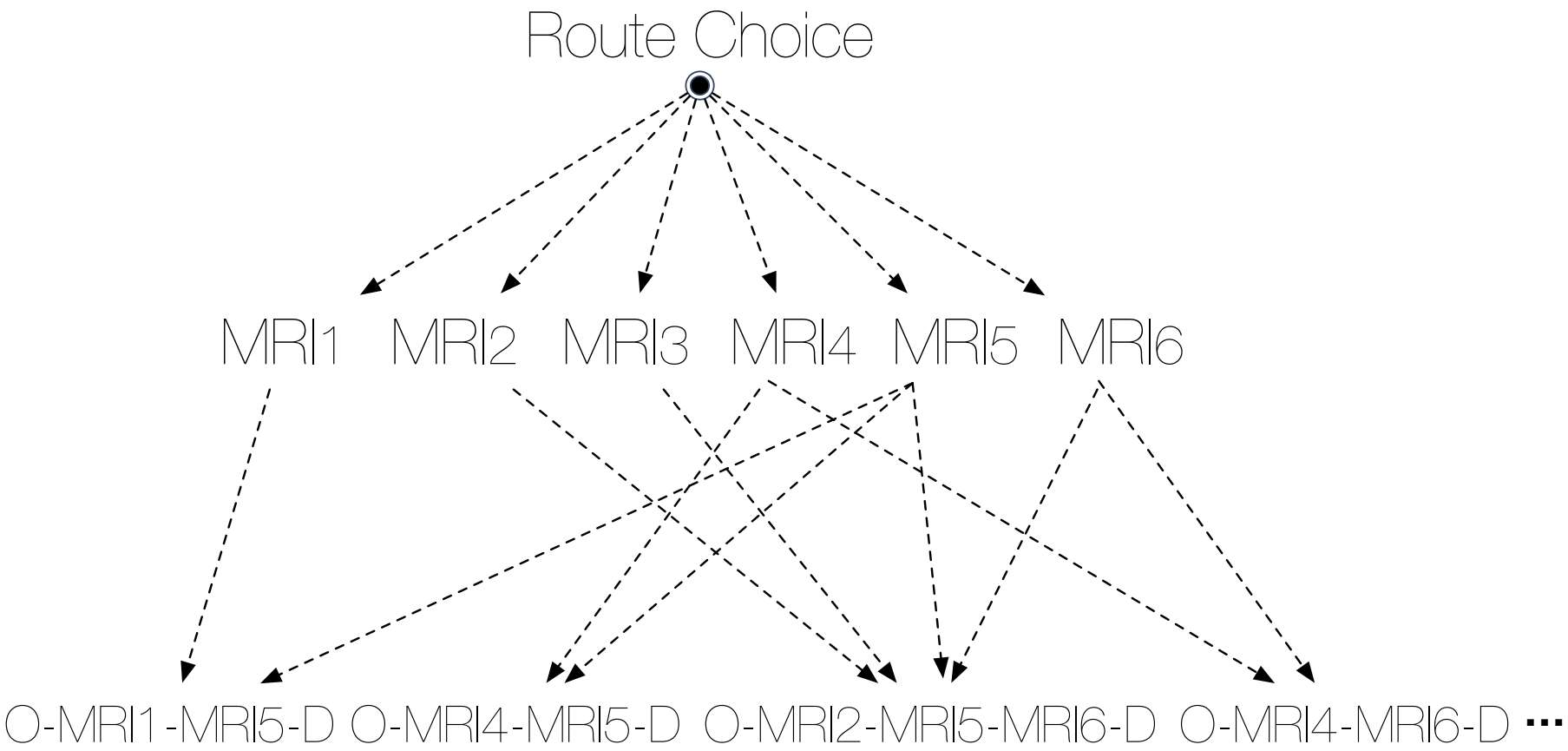


CNL with MRIs

- Each MRI is a nest.
- An alternative i belongs to nest m if MRI m appears in the sequence i.

- In the topological network there are about $\sim$ 7000 links that would correspond to nests.
- With the MRI approach we only have 6 nests.

The underlying MRI nesting structure



CNL specification

with the MRI approach we are able to test CNL specifications in a real network

$$G(y) = \sum_{m=1}^{M} \left(\sum_{j=1}^{J} \alpha_{jm}^{\frac{\mu_m}{\mu}} y_j^{\mu_m} \right) \tag{1}$$

1. Impose α[1] and estimate μ_{m}[2]
2. Estimate both α and μ_{m}
   1. Parametrization of α to reduce the # of parameters $\alpha_{im} = \frac{\delta_{im} e^{w_m}}{\sum \delta_{jm} e^{w_\ell}}$
   2. w for groups of similar alternatives
3. Regress μ_{m} to MRI characteristics

[1] Parameter capturing the level of membership in a nest.

[2] Nest specific scale.

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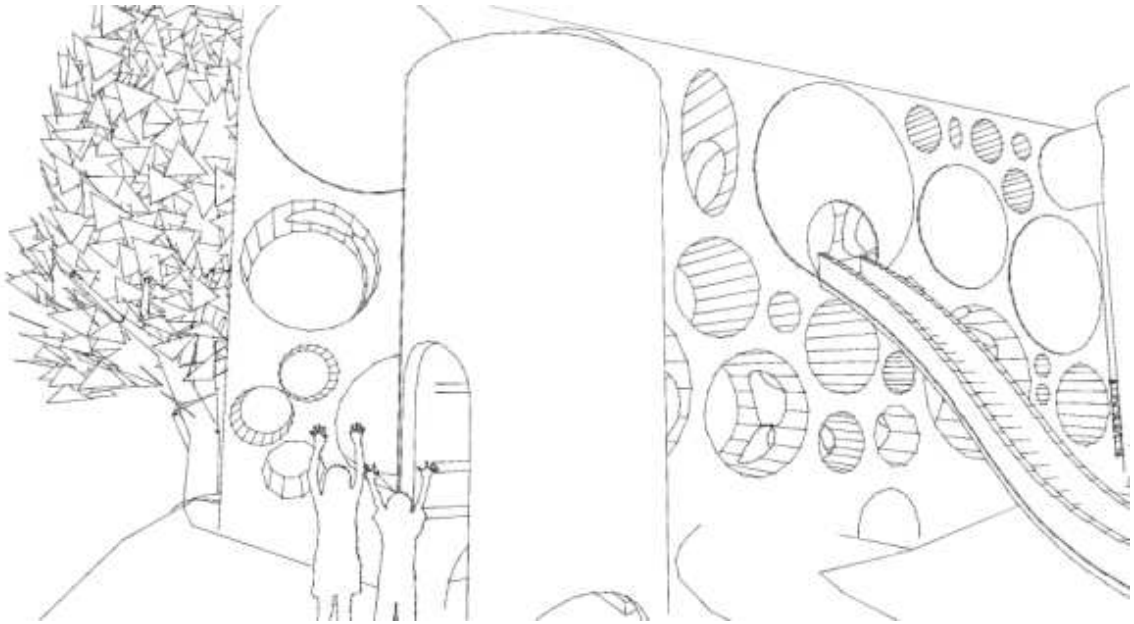
Conclusion

1. Capturing correlation in a behavioral realistic way entails additional model complexity.
2. In the context of route choice, the estimation of the models such as CNL for large networks is cumbersome.
3. With the `MRI` approach we are aiming at making the models simpler.



Thank you!

evanthia.kazagli@epfl.ch

transp-or.epfl.ch